Effect of Different Irrigation Levels on Growth, Yield and Fruit Quality of Mango cv. Keitt Grown Under Screen House

Aly, M. A. M.*, G. Abdel-Nasser, A. A. Ismaeil*** and G.F.M. Bayoumi***
*Plant Production Dept., Faculty of Agriculture (Saba Basha)- Alexandria University
**Soil and Agricultural Chemistry Dept., Faculty of Agriculture (Saba Basha) - Alexandria University
*** Hort. Res. Institute, Agric. Res. Center, Giza- Egypt.

ABSTRACT: The present study was conducted during two successive seasons 2015 and 2016 on ten years old of Mango (*Mangifera indica* L.). cv. Keitt cultivar trees grew in El-Bosaily governmental farm at the North West of the Nile Delta, Behira governorate, Egypt. The study was conducted to test the effect of cultivation method and different irrigation levels on growth, yield and fruit quality of mango and also water requirements and water use efficiency. White screen house and open field (control) were arranged in the main plots and three irrigation levels (50, 75 and 100% of ET_0) were arranged in sub-plots. Results revealed that screen house cultivation gave the highest values of all vegetative growth as shoot length, shoot thickness, leaf area, and chlorophyll concentration index. Also, gave the better fruit set, best yield and yield components as (fruit weight, number of fruits/tree, fruit yield/ tree, gross fruit yield, fruit length, fruit width and fruit firmness. On the other side, its recorded the highest mean value of chemical composition (TSS, acidity, TSS/acidity ratio, total sugar, reducing sugar, non-reducing sugar, total carbohydrates and VC) compared to open field cultivation during both experimental season. Furthermore, data showed that 100 % of ET_0 irrigation level significantly increased all studied characters as compared with other treatments. The main advantage of the present study is its potential for saving water and increasing the water productivity of mango.

Keywords: Mango, Keitt cultivar, screen house, irrigation levels, vegetative growth, yield, fruit quality.

INTRODUCTION

Mango (*Mangifera indica* L.) belongs to the family Anacardiaceae considered as one of the most important fruits of the tropical and subtropical countries. In Egypt, mango ranks the third after citrus and grapes, whereas its total area of fruitful orchards reached approximately 101303 ha producing about 712537 tons annually (FAOSTAT, 2013).

Mango fruit conquers the 2nd position as a tropical crop, behind only bananas in terms of production and acreage used (Muchiri *et al.,* 2012). It has been well documented that mango fruits are an important source of micronutrients, vitamins and other phytochemicals. Moreover, mango fruits provide energy, dietary fiber, carbohydrates, proteins, fats and phenolic compounds (Tharanathan *et al.,* 2006), which are vital to normal human growth, development and health (Jahurul *et al.,* 2015).

Water deficit is used as flowering inducer for mangoes in semiarid regions (Bassoi, 2012). However, irrigation management strategies based on controlled deficit have often been employed empirically; causing many problems such as a lack of differentiation of vegetative buds in inflorescence and physiological disorders caused water stress lack of control. Management based on water deficit, when properly applied, can increase water use efficiency, improving fruit yield and quality without negative long-term effects (Spreer *et al.,* 2009).

Drip irrigation has the greatest potential for the efficient use of water and fertilizers. The limited area of wetting under trickle irrigation reduces the active root zone and also the foraging area of plants to draw water and nutrients from the soil. For minimizing the cost of irrigation and fertilizers, adoption of drip irrigation with fertilization is essential which will maximize the nutrient uptake, while using minimum amount of water and fertilizer.

Although screen houses have been used for many years the recent upsurge in their popularity, which is largely due to the desire to reduce pesticide application, requires increased understanding of their climate. Little research on screen house climate and water use has been previously reported, and pressure on water resources makes this information timely. An early study of screen house climate, Ross and Gill (1994) reported general features, but did not parameterize the house and screen structures, and therefore cannot be used to predict the behavior of modern screening materials and screen house structures, or the interaction of climate with screen houses covering several thousand square meters of cultivated area (Desmarais, 1996).

The objective of this study was to optimize the effect of different irrigation levels on growth, yield and fruit quality of mango (*Mangifera indica* L. cv. Kit) grown under screen house and open field.

MATERIALS AND METHODS

This study was carried out during two successive seasons 2015 and 2016 on ten years old Mango (*Mangifera indica* L.). cv. Keitt cultivar trees grown in El-Bosaily governmental farm at the North West of the Nile Delta, Behira governorate, Egypt. The farm is located at 31˚ 10.102′ N and 29˚ 58.085′ E with altitude of (15 m) under sea level. The distance between trees was 2.0 m and distance between rows is two meters. The rows were oriented from North to South. The greenhouse area was 4200 m^2 (70 m Length x 60 m width). The Greenhouse was covered by white screen net. The opening diameter of white net screen was 0.28 mm, and cell size was 3 mm x 7.4 mm.

A surface soil sample (0-30cm depth) was collected before starting the experiment to identify some physical and chemical properties of this soil as shown in Table (1).

Table (1). Chemical and physical properties of the soil of the experiment analyzed before cultivation

Chemical properties								
EC dS m^{-1}	pH	Ca^{++} meq/l	Mg^{++} meq/l	Na^{+} meq/l	K^{+} meq/l	HCO^{3}- meq/l	Cl – meq/l	SO_4^{2-} meq/l
1.55	7.67	3.5	2.0	8.07	1.17	1.5	9.0	4.24
Physical properties								
Sand %	**Clay %**	**Silt %**	**Texture**	**FC %**	**PWP %**	**Bulk density g/cm^3**		
95.31	4.33	0.36	Sandy	16.77	5.65	1.44		

This area is characterized by a semi-arid climate; the weather is hot and dry from May to August. Some climatological data of the experimental site were taken from El-Bosaily weather station for inside the green house and the open filed. The experiment was arranged in spilt plot design. The treatments can be illustrated as follows:

A) Main plots (cultivation method)
• Inside screen house
• Open filed
B) Sub-plots (Irrigation levels)
• 50 % of reference evapotranspiration (ET_0),
• 75 % of reference evapotranspiration (ET_0), and
• 100 % of reference evapotranspiration (ET_0)
Each sub-plot consisted of ten rows 35 tree/row.

Measurements:

Samples of five trees from the three central rows of each plot were taken to determine the growth parameters at the end of the season as follows:

Vegetative growth:

- Tree height (cm)
- Shoot length (cm)
- Shoot thickness (cm)
- Leaf area (cm^2) was determined as the following equation (Ahmed and Morsy (1999):

$$\text{leaf area}(cm^2) = \text{leaf length} \times \text{leaf width} \times (2/3)$$

- Number of shoots/ tree
- Number of leaves/ shoot
- Total chlorophyll in the fresh leaves was determined as SPAD units by using Minolta chlorophyll meter (SPAD, 501).

Fruit set and drop (%):

In the spring, four branches were chosen from each tree and marked. The number of flowers, number of fruits on these branches and the remained fruits on these branches were counted then the initial and final fruit set and fruit drop percentages were calculated according to the suitable equation.

Initial fruit set (%):

On each replicate tree, five shoots distributed on different sides were chosen randomly and tagged at the beginning of the growing season. All inflorescences on each shoot were counted and recorded. Three weeks after flowering initial fruit set percentage on replicate trees of the studied treatments was calculated from the following formula:

$$\text{Initial fruit set}(\%) = \frac{\text{FR}\times 100}{(\text{AVF}\times\text{NF})}$$

FR is the number of fruits/shoot

AVF is the average number of flowers/ inflorescence

NF is the number of inflorescences/ shoot

Final fruit set (%):

Sixty days after flowering, final fruit set percentage was calculated in the same sequence mentioned above for the initial fruit set percentage according to the following formula:

$$\text{Final fruit set}(\%) = \frac{\text{No.of fruitlets}}{\text{No.of opend flowers}}\times 100$$

Fruit drop (%):

Fruit drop %: was calculated by counting the number of dropping fruits from the middle of June till the commercial harvesting time under experimental conditions (Middle of June), then expressed as a percentage from the whole number of fruits remained on the tree at the middle of June according to this formula:

$$\text{Fruit drop }(\%) = \frac{\text{No. of dropped fruits}}{\text{No. of set fruitlets}}\times 100$$

Yield

The produced fruit yield on each replicate tree resulting from the applied treatments was expressed as number of fruits/tree, weight of fruits in kg/ tree which was attained at harvest stage and the gross yield as ton/fed.

Fruit characteristics:

Sample of 10 fruits per tree from each replicate was collected randomly, when the fruits were yellow colored in both seasons, and then transported quickly to the laboratory to determine physical and chemical fruit characteristics.

Fruit physical characteristics

Regarding fruit physical characteristics, samples of 10 fruits from each replicate tree i.e. 30 fruits for each of the applied treatment was picked randomly at harvest to determine the following

Average fruit weight (g/ fruit):

Fruit samples were weighted and the average fruit weight for each replicate was calculated.

No. fruits/tree

Weight of fruits/tree (kg)

At harvest time, yield of each treatment was recorded as kg/tree by multiplying number of fruits × average weight of fruit. Also, yield produced as kg/feddan was expressed by multiply the weight of fruits/tree x number of trees/feddan (700 trees/ fed).

Average fruit length (L) and diameter (D) were measured by using hand caliper.

Fruit firmness:

was expressed as (pound / Inch^2) according to (Magness and Taylor, 1982). Flesh firmness was measured in two opposite sides of the fruit using magness taylor pressure tester.

Fruit chemical characteristics:

Samples of 10 fruits from each replicate i.e. 30 fruits for each of the applied treatment was picked randomly at harvest to determine the following parameters:

Total soluble solids of fruit juice (TSS %) was measured as percentage of TSS by hand refractometer according to Chen and Mellenthin (1981).

The percentage of total acidity was determined in fruit juice according to Chen and Mellenthin (1981) five milliliters from the obtained juice were used to determine the titratable acidity. The titratable acidity was expressed as mg malic acid / 100 milliliters fruit juice.

TSS/ acid ratio were calculated for each replicate of the applied treatments.

Total sugars were determined in fresh fruit samples according to Malik and Singh (1980). Sugars were extracted from 5 grams fresh weight and determined by phenol sulfuric and Nelson arsenate –molybadate colorimetric methods for total and reducing sugars, respectively. The non-reducing sugars were calculated by difference between total sugars and reducing sugars.

Vitamin C (as Ascorbic acid) was determined in the juice by titration with 2, 6 dichlorophenol-indo-phenol (AOAC, 1985) and calculated as mg per 100 ml of juice.

Total soluble carbohydrates were determined, quantitatively, in the fruit of Mango by Anthron method according to Yemm and Willis (1954) and Mahadevan and Sridhar (1986) as follows:

Extraction was carried out by grinding dry matter in Mahadavaine buffer (sodium citrate buffer, pH 6.8). Extracts were homogenized for 3 minutes and centrifuged at 4000 rpm for 15 min. the supernatant was then used to determine total soluble carbohydrates. Ten grams of the cut flesh were taken and extracted by distilled water according to AOAC (1980). In order to determine the total soluble carbohydrates by the above-mentioned, the extract was heated at 70℃ in water both for 10 minutes. 50 micro liter of the extract were then poured into test tubes, 3ml of the anthron regent were added to each tube and the tubes were placed in water both at 100℃ for 10 min. the reagent blank tubes were treated is similar way, and the absorbance of the mixture was measured at 625 nm. The standard curve was prepared from glucose.

Crop Water-Use Parameters

Systematic determination of several water parameters was carried out to provide basic information for the interpretation of experimental results. The following parameters were determined:

Reference Evapotranspiration (ET_0)

The reference evapotranspiration (ET_0) was calculated with FAO Penman- Monteith equation (Allen *et al.,* 1998) according to the climatic data collected from the El-Bosaily weather station. The equation is expressed as:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma(1+0.34U_2)}$$

Where:

ET_0	Reference evapotranspiration, mm day^{-1} ;
R_n	Net radiation at the crop surface, MJ m^{-2} day^{-1};
G	Soil heat flux density, MJ m^{-2} day^{-1} (Generally very small and assumed to be zero for daily calculations);
T	Mean daily air temperature at 2.0 m height, °C;
U_2	Wind speed at 2 m height, m s^{-1};
e_s	Saturation vapor pressure at 1.5 to 2.5 m height, kPa;
e_a	Actual vapor pressure at 1.5 to 2.5 m height, kPa;
e_s - e_a	Saturation vapor pressure deficit, KPa;
Δ	Slope vapor pressure-temperature curve, kPa℃$^{-1}$; and
γ	Psychrometric constant, kPa℃$^{-1}$

Crop Evapotranspiration (ET_c)

Crop evapotranspiration (ET_c) is the daily use of water by trees and calculated from the following equation (Allen *et al.*, 1998):

$$ET_c = K_c \times ET_0$$

Where:
K_c is the crop coefficient

Crop Water Requirements

The crop water requirements were calculated according to the Penman-Monteith equation (Allen *et al.*, 1998) using the following equation (Cuenca, 1989):

$$ET_{drip} = K_r \times K_c \times ET_0$$

Where:
ET_{drip} is the crop water requirements under drip irrigation system
K_r is the reduction factor that reflects the percent of soil covering by crop canopy. K_r can be calculated by the equation described in Karmeli and Keller (1975):

$$K_r = \frac{GC}{0.85}$$

Where:
GC is the ground cover fraction (plant canopy area divided by soil area occupied by one tree, assumed as 0.7).
K_c is the crop coefficient ranging from 0.65 (for initial stage) to 0.91 (for development stage)

Applied Irrigation Water

The amount of applied irrigation water was calculated according to the following equation (Vermeiren and Jopling, 1984).

$$AIW = \frac{ET_{drip}}{(1\text{-}LR) \times E_i}$$

Where:
AIW is the depth of applied irrigation water (mm),
E_i is the irrigation efficiency of the drip irrigation system (assumed as 0.90), and LR is the leaching requirements used for salt leaching in the root zone depth (assumed as 0.15). Irrigation time was calculated before an irrigation event by collecting the actual emitter discharges according to the equation given by Ismail (2002) as follows:

$$t(hr) = \frac{AIW \times A}{q}$$

Where: t is the irrigation time (hr),
A is the wetted area (m^2), and
q is the emitter discharge (m^3/hr).

Water Consumptive Use (WCU)

Plant water consumptive use was calculated by the following formula

$$CU(mm) = K_c \times K_r \times ET_0$$

Where: CU is the Mango water consumptive use (mm/day).

Water Use Efficiency

Irrigation Water Use Efficiency (IWUE) was calculated according to Sharma *et al.* (2015) as follows:

$$IWUE(kg/m^3) = \frac{\text{Mango Yield(kg/fed)}}{\text{Applied Irrigation Water}(m^3/\text{fed})}$$

Consumptive Water Use Efficiency (CWUE) was calculated according to the following equation:

$$CWUE(kg/mm) = \frac{\text{Mango Yield(kg/fed)}}{\text{Consumptive Water(mm/fed)}}$$

Statistical analysis:

Results of the measured parameters were subjected to computerized statistical analysis using MSTAT package for analysis of variance (ANOVA) and mean of treatments were compared using LSD at 0.05 probability level according to Snedecor and Cochran (1990).

RESULTS AND DISCUSSION

1. Vegetative growth

Results recorded in Table (2) revealed that screen house treatment significantly increased all vegetative growth (shoot length, shoot thickness (cm), leaf area (cm^2) and chlorophyll index) in both seasons. These findings are confirmed with Agrawal *et al.* (2005) on mango cv. Dashehari. Medany *et al.* (2009) on mango cv. Keitt cultivar found that the screen house was superior for plant growth, flowering, and yield.

Regarding to irrigation levels effect, increasing application rate up to 100 % gradually and significantly increased the values of all vegetative growth in both seasons. These results agreed with those obtained by Dos Santos *et al.* (2015), Soothar *et al.* (2016) and Wei *et al.* (2017) on Mango.

The increase in growing parameters with screen house condition was due to the suitable condition of available water in active root zone along time and optimal climatic conditions.

The deficit irrigation is an irrigation management that induce water deficits to plants at development stages, in which the fruit growth and quality have low sensitivity to water stress, not hinder its potential productivity, in order to increase water use efficiency.

Table (2). Effect of cultivation methods and irrigation levels on the vegetative growth of mango cv. Keitt cultivar during 2015 and 2016 growing seasons

Treatment	Shoot length (cm)		Shoot thickness (cm)		Leaf area (cm^2)		Chlorophyll index (SPAD reading)	
	2015	2016	2015	2016	2015	2016	2015	2016
A) Cultivation method								
Screen house	39.62	46.39	8.09	8.30	73.36	79.15	46.37	49.91
Open field	37.66	42.63	7.18	7.38	69.23	75.16	44.63	47.17
LSD (0.05)	**0.40**	**0.76**	**0.16**	**0.09**	**2.41**	**1.50**	**1.89**	**0.44**
B) Irrigation levels								
50% of ET_0	34.64	39.92	6.87	7.03	63.93	69.10	40.80	43.52
75% of ET_0	38.49	44.33	7.64	7.81	71.04	76.87	45.34	48.35
100% of ET_0	42.77	49.29	8.39	8.68	78.93	85.41	50.37	53.75
LSD (0.05)	**0.04**	**0.13**	**0.17**	**0.006**	**0.12**	**0.12**	**0.09**	**0.05**
AXB Interaction (LSD 0.05)	**0.06****	**0.18****	**0.24****	**0.01****	**0.17****	**0.17****	**0.14****	**0.08****

2. Fruit set and drop (%)

The data concerning the effect of screen house treatments on the percentage of initial fruit set and final fruit set of mango during 2015 and 2016 seasons are presented in Table (3). The data revealed that mango trees which grown under screen house significantly increased initial fruit set and final fruit set percentages as compared with the open field. These results agreed with those obtained by Pratima *et al.* (2016) on kiwi fruit cultivar and Medany *et al*. (2009) on mango. On the other hand, irrigation levels treatments at 100 % ET_0 increased initial fruit set and final fruit set percentage significantly as compared with others treatments during both experimental seasons. Such findings are in agreements with those of Jiskani *et al*. (2007), Yildirim *et al*. (2009) and Dos Santos *et al*. (2016) on 'Tommy Atkins' mango.

Table (3). Effect of cultivation methods and irrigation levels on the fruit set and fruit drop (%) of Mango cv. Keitt during 2015 and 2016 seasons

Treatment	Initial fruit set (%)		Final fruit set (%)		Fruit drop (%)	
	2015	2016	2015	2016	2015	2016
A) Cultivation method						
Screen house	12.14	13.67	2.98	3.90	71.44	79.34
Open field	11.66	13.02	2.72	3.33	67.89	73.80
LSD (0.05)	**0.54**	**0.61**	**0.74**	**0.11**	**0.64**	**3.75**
B)Irrigation levels						
50% of ET_0	10.77	12.05	2.58	3.26	77.06	83.64
75% of ET_0	11.86	13.39	2.53	3.58	69.44	76.32
100% of ET_0	13.06	14.58	3.15	3.99	62.49	70.74
LSD (0.05)	**0.29**	**0.52**	**0.05**	**0.08**	**0.12**	**4.71**
AXB Interaction(LSD0.05)	**ns**	**ns**	**ns**	**ns**	**0.18****	**ns**

3. Yield and fruit characteristics of Mango

Results presented in Tables (4 and 5) revealed that the yield and some physical fruit characteristics of mango Keitt cultivar as (fruit weight, number of fruits/ tree, yield weight per tree and gross yieldper fed, fruit length, fruit width and fruit firmness) of mango trees which grown under screen house significantly increased compared with open field in both seasons.

These findings are confirmed with Medany *et al*. (2009) on Mango cv. Keitt cultivar who stated that microclimate under the white net makes proper microclimate for tropical fruits under Egyptian conditions. Also, similar results were obtained by Spreer and Müller (2011) on Mango 'Chok Anan' fruit.

On the other side, Tables (4 and 5) cleared that irrigation level treatment at 100 % significantly increased all yield and some physical fruit characteristics of mango (fruit weight, number of fruits/ tree, yield weight per tree and gross yield per fed, fruit length, fruit width and fruit firmness) compared with other treatments during both seasons. Such findings are in agreements with those of Zuazo *et al.* (2011), Schulzea *et al*. (2013), Carr (2014) and Wei *et al.* (2017) on Mango, Da Silva *et al.* (2014) on Mango cultivars (Bourbon, Haden, Palmer, Parwin and Tommy Atkins) and Dos Santos *et al.* (2014) on 'Tommy Atkins' Mango.

Table (4). Effect of cultivation methods and irrigation levels on the fruit yield of Mango cv. Keitt during 2015 and 2016 seasons

Treatment	Fruit weight (g)		Number of fruits/tree		Fruit yield/ tree (kg /tree)		Fruit yield (ton/fed)	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
A) Cultivation method								
Screen house	546.52	584.28	46.92	52.26	25.82	30.77	18.59	22.15
Open field	534.41	564.22	41.19	46.25	22.17	26.29	15.96	18.92
LSD (0.05)	**6.76**	**7.07**	**0.31**	**0.28**	**3.04**	**2.47**	**2.19**	**1.78**
B) Irrigation levels								
50% of ET_0	484.62	514.92	39.77	44.00	19.30	22.64	13.89	16.30
75% of ET_0	538.47	572.13	44.19	48.88	23.81	27.99	17.14	20.15
100% of ET_0	598.30	635.70	48.20	54.90	28.89	34.94	20.79	25.16
LSD (0.05)	**0.29**	**046**	**0.11**	**0.06**	**0.98**	**0.56**	**0.17**	**0.41**
AXB Interaction(LSD0.05)	**0.42****	**0.65****	**0.15****	**0.09****	**ns**	**ns**	**ns**	**ns**

Table (5). Effect of cultivation methods and irrigation levels on some fruit physical characteristics of Mango cv. Keitt cultivar during 2015 and 2016 growing seasons

Treatment	Fruit length (cm)		Fruit width (cm)		Fruit firmness ($lb/inch^2$)	
	2015	2016	2015	2016	2015	2016
A) Cultivation method						
Screen house	13.52	13.94	9.24	9.71	30.57	32.61
Open field	12.91	13.35	**8.77**	9.55	28.92	30.67
LSD (0.05)	**0.11**	**0.25**	**0.07**	**0.04**	**0.51**	**0.61**
B)Irrigation levels						
50% of ET_0	11.86	12.23	8.08	8.64	26.67	28.37
75% of ET_0	13.17	13.59	8.97	9.60	29.64	31.53
100% of ET_0	14.63	15.11	9.97	10.66	32.93	35.03
LSD (0.05)	**0.01**	**0.01**	**0.005**	**0.005**	**0.03**	**0.03**
AXB Interaction (LSD 0.05)	**0.02****	**0.02****	**0.007****	**0.007****	**0.05****	**0.04****

With respect to the fruit physical parameters, deficit irrigation tended to yield superior fruits, as the overall fruit size distribution was more favorable and the fraction of undesirable mangoes in the lower size classes was reduced. An interaction between fruit size and the significantly lower amount of fruits per tree can be assumed, based on the above-mentioned effect of water deficit on fruit drop. The present results showed reduced yield under deficit irrigation as compared to the fully irrigated mango trees and increased mango productivity under screen house cultivation than open field conditions.

Data presented in Table (6) revealed that the screen net treatment significantly increased the fruit chemical quality during 2015 and 2016 seasons such as (TSS, acidity, TSS/acidity ratio, VC content, total sugar (%), reducing sugar (%), Non-reducing sugars (%), Total carbohydrates (%) and Carotene). These findings are confirmed with Medany *et al*. (2009) on mango cv. Keitt and Spreer and Müller (2011) on Mango ‘Chok Anan’ fruit.

Also, irrigation level treatments at 100 % significantly increased all fruit chemical quality in both seasons (TSS, acidity, TSS/acidity ratio, VC content, total sugar (%), reducing sugar (%), Non-reducing sugars (%) and total carbohydrates (%)). These results are in agreement with those obtained by Zuazo *et al.* (2011) and Wei *et al*. (2017) on Mango; Abdel-Razik (2012) on Mango cultivars namely Ewais and Tomy Atkins and Barakat *et al.* (2015) on the banana.

Table (6). Effect of cultivation methods and irrigation levels on fruit chemical characteristics of mango cv. Keitt cultivar during 2015 and 2016 seasons

Treatment	TSS (%)		Acidity (%)		TSS/Acidity (%)		Total sugars (%)	
	2015	2016	2015	2016	2015	2016	2015	2016
A) Cultivation method								
Screen house	18.34	20.00	049	0.52	36.89	38.70	11.19	14.05
Open field	16.81	18.22	0.47	0.49	35.94	37.05	10.15	11.82
LSD (0.05)	**0.71**	**0.31**	**0.01**	**0.01**	**1.07**	**0.84**	**045**	**0.67**
B)Irrigation levels								
50% of ET_0	15.76	17.14	0.43	0.45	36.56	37.89	9.57	11.60
75% of ET_0	17.51	19.04	0.48	0.50	36.54	37.87	10.63	12.89
100% of ET_0	19.46	21.15	0.53	0.56	36.14	37.87	11.81	14.32
LSD (0.05)	**0.05**	**0.08**	**0.00**	**0.001**	**0.72**	**0.02**	**0.03**	**0.03**
AXB Interaction (LSD0.05)	**0.06****	**0.12****	**0.002****	**0.002****	**ns**	**ns**	**0.04****	**0.04****

Table (6). Cont.…

Treatment	Reducing sugars (%)		Non-reducing sugars (%)		VC (mg/100ml)		Total carbohydrates (%)	
	2015	2016	2015	2016	2015	2016	2015	2016
A) Cultivation method								
Screen house	6.06	7.42	5.**13**	6.56	37.22	40.18	16.51	18.61
Open field	**4.83**	6.79	**5.**32	5.03	34.77	38.42	15.07	17.23
LSD (0.05)	**0.92**	**0.55**	**0.55**	**0.44**	**0.79**	**1.86**	**0.65**	**0.90**
B)Irrigation levels								
50% of ET_0	4.88	6.37	4.69	5.22	32.27	35.24	14.16	16.07
75% of ET_0	**5.43**	7.08	**5.22**	5.81	**35.86**	39.15	**15.73**	17.85
100% of ET_0	6.03	7.87	5.79	6.35	39.86	43.50	17.48	19.84
LSD (0.05)	**0.05**	**0.03**	**0.03**	**0.17**	**0.06**	**0.09**	**0.03**	**0.04**
AXB Interaction (LSD0.05)	**0.06****	**0.04****	**ns**	**ns**	**0.09****	**0.13****	**0.05****	**0.06****

4. Crop water requirements

The reference evapotranspiration calculated according to Penman-Montieth equation are illustrated in Table (6). The data indicated that reference evapotranspiration was higher at open field than screen house. Also, calculated crop evapotranspiration reached to 662.3, 993.5 and 1324.7 mm per season during 2015 growing season for 50, 75 and 100% of ET_0, respectively. The corresponding values for 2016 growing season are 642.5, 963.8 and 1285.0 mm per season , respectively.

The Kc values, used to calculate the crop evapotranspiration during the evaluated stages, were 0.63 to 0.91, according to Cotrim *et al.* (2011). This method considers the number of days after flowering to find the crop coefficient.

Irrigation requirement of mango is still not well investigated. A progressive crop coefficient (Kc) ranging from 0.4 (flowering) to 0.8 (fruit growth) was proposed to calculate crop water requirement (de Azevedo *et al.*, 2003). Also, crop coefficient is still under study because until now crop coefficient of mango not defined and has little investigation.

The present study gave proposed values of Kc as described by the following equation:

The first season

$Kc = 7E\text{-}08X^3 - 5E\text{-}05X^2 + 0.0076X + 0.6486 \quad R^2 = 0.9596$

The first or second season

$Kc = 6E\text{-}08X^3 - 4E\text{-}05X^2 + 0.0066X + 0.7235 \quad R^2 = 0.9987$

Where X represent the days in the year

Table (7). The reference evapotranspiration (ETo) during 2015 and 2016 growing seasons of mango at El-Bosaily governmental farm, Behira governorate, Egypt.

Month	ET_0 inside the screen house (mm/day)		ET_0 in open field (mm/day)	
	2015	2016	2015	2016
Jan	1.13	1.14	1.34	1.30
Feb	1.17	1.17	1.74	1.95
March	1.38	1.51	2.47	2.81
April	1.74	1.59	3.61	3.86
May	1.89	1.65	4.49	4.61
Jun	1.88	1.64	4.78	5.16
July	1.83	1.50	4.99	5.16
Aug	1.70	1.33	4.62	4.39
Sept	1.46	1.12	3.69	3.43
Oct	1.36	0.86	2.54	2.45
Nov	1.11	0.92	1.44	1.45
Dec	0.94	0.97	1.05	1.11
Average	**1.46**	**1.28**	**3.06**	**3.14**

The applied irrigation water of mango was 1474.2, 2211.3 and 2948.4 m^3/fed during 2015 growing season for screen house and open field cultivation for 50, 75 and 100% of ET_0, respectively. The corresponding values were 1436.4, 2154.6 and 2872.8 m^3/fed, respectively, for 2016 season.

5. Water use efficiency (WUE)

Where water is a limiting factor for production, deficit irrigation can enhance WUE, so that the available water is better allocated. Water use efficiency (WUE) calculated as the harvested yield (kg) per volume of irrigation water (m^3) according to FAO recommendations (Doorenbos and Kassam, 1979). WUE of 50% and 75% of ET_0 was higher compared to the 100% of ET_0

as the control treatment. Out of several biotic and abiotic factors responsible, optimum water management is one of the most important factors that significantly influence productivity as well as the quality of the produce (Bhriguvanshi *et al.*, 2012).

The water use efficiency (IWUE and CWUE) are illustrated in Table (8). The results indicated that irrigation water use efficiency (IWUE) was increased in screen house cultivation over the open field cultivation by about16.78% for both growing seasons. Also, consumptive water use efficiency (CWUE) was more pronounced at screen house than open field conditions by 16.90 and 16.73% for 2015 and 2016 growing seasons. This trend is true because the increasing values are due to the high productivity of mango under the screen house cultivation.

Table (8). Irrigation water use efficiency and water consumptive use efficiency of mango cv. Keitt cultivar during 2015 and 2016 seasons as affected by cultivation methods and irrigation levels.

Treatment	IWUE kg/m^3		CWUE kg/mm	
	2015	2016	2015	2016
A) Cultivation method				
Screen house	8.70	10.58	19.37	23.65
Open field	7.45	9.06	16.57	20.26
LSD (0.05)	0.94*	0.91**	2.09*	2.03**
B) Irrigation levels				
50% of ET_0	9.42	11.32	20.97	25.37
75% of ET_0	7.75	9.35	17.25	20.91
100% of ET_0	7.06	8.76	15.70	19.58
LSD (0.05)	0.21**	0.20**	0.47**	0.45**
AXB Interactions (LSD 0.05)	*	ns	*	ns

The IWUE and CWUE were affected by irrigation levels, in which the values were decreased with increasing the irrigation level. The less irrigation level (50% of ETo) reached the highest value for both growing seasons. This trend is true because increasing irrigation level decreased the values of water use efficiency. The WUE can be doubled under deficit irrigation as compared to full irrigation. With deficit irrigation, water productivity was 9.72 and 11.32 kg/m^3 for 2015 and 2016 growing season, against 7.06 and 8.76 kg/m^3 for full irrigation, respectively.

Water for irrigation is an increasingly scarce resource in arid and semi-arid regions and, therefore, a limiting factor for a sustainable increase in agricultural production. The present results support the theory that deficit irrigation in general, is appropriate to make mango production more sustainable. As shown in this study, deficit irrigation especially offers an alternative to conventional irrigation without any detrimental effect on fruit quality. Considering the large increase in WUE, deficit irrigation has shown to be practical for mango production.

Irrigation of mango is necessary to ensure high fruit yields and a favorable fruit quality. The replenishment of the water use by ETc to 100% as it can be calculated by standard methods is the most solid way to ensure a high productivity of the mango trees. It was shown, that the number of fruit rather than the fruit size influences the total yield. High fruit yield and favorable fruit quality are counteracting and the exact control of both parameters by means of irrigation seems to be difficult. While there is a negative correlation between the number of fruits on the tree and the average fruit size, the influence of irrigation on fruit size remains important.

Where water is a limiting factor to production, deficit irrigation can enhance WUE, so that the available water is better allocated. Knowledge about the different stages of fruit growth and fruit quality increase on the tree can help farmers to schedule irrigation accordingly and make use of drought stress responses of mangoes. Deficit irrigation strategies can save considerable amounts of water without affecting the yield to a large extend, possibly increasing the average fruit weight apparently without negative long-term effects.

Finally, the main advantage of deficit irrigation is its potential for saving water. Higher WUE is an important factor to sustainably expand their irrigated areas. Lower water consumption also saves costs for water pumping and storage. In conclusion, farmers with less access to water may benefit from using deficit irrigation in mango production.

CONCLUSIONS

Results of the present study recommend irrigation of mango (*Mangifera indica*, L) cv. Keitt at 100% of reference evapotranspiration (ET_0) and cultivated under screen house condition to obtain the positive effect on vegetative growth, productivity and fruit quality through increasing fruit set percentage and saving water.

REFERENCES

Abdel-Razik, A.M. (2012). Effect of different irrigation regimes on quality and storability of mango fruits (*Mangifera indica* L.). J. Hort. Sci. Ornam. Plants, 4 (3): 247-252

Agrawal, N., H. G. Sharma, S. Agrawal. A. Dixit and P. Dubey (2005). Comparative study of drip irrigation and surface method with and without plastic mulching in mango cv. Dashehari. Haryana. J. Hort. Sci., 34 (2/1): 9-11.

Ahmed, F.F. and M.H. Morsy (1999). A new method for measuring leaf area in different fruit species. Minia. J. Agric. Res. Of Develop. 19: 97-105.

Allen, R.G., L.S. Pereira, D. Raes and M. Smith (1998). Crop evapotranspiration-guide lines for computing crop water requirement. Food Agric. Organ. Rome, Italy, pp: 300.

AOAC (1980). Official Methods of Analysis. 13thed Association of Official Analytical Chemists. Washington, D.C. pp 376-384

AOAC (1985). Official Methods of Analysis. Association of Official Analytical Chemists Washington, D.C. pp 490-510

Barakat, M.R., S. El-Kosary, T.I. Borham and M.H. Abd-ElNafea (2015). Effect of hydrogel soil addition under different irrigation levels on Grandna in Banana Plants. J. Hort. Sci. Ornam. Plants, 7 (1): 19-28.

Bassoi, L. H. (2012). Oportunidade para irrigação com déficit no semiárido. In: workshop internacional de inovaçõestecno-lógicasnairrigação, 4, Fortaleza.

Bhriguvanshi, S.R, T. Adak, K. Kumar, V.K. Singh, A. Singh, and V.K. Singh (2012). Impact of fertigation regimes on yield and water use efficiency of Mango (*Mangifera indica* L.) under subtropical condition, Ind. J. Soil Cons, 40(3): 252-256.

Carr, M. K. V. (2014). The water relations and irrigation requirements of mango (*Mangifera indica* l.): A review, 50(1): 1-23.

Chen, B.M. and W.M. Mellenthin (1981). Effect of harvest date on ripening capacity and post-harvest life of Anjou pears. J. Amer. Soc. Hort. Sci., 106: 38-42.

Cotrim, C.E., M. A. C. Filho, E. F. Coelho, M M. Ramos, P. R. Cecon (2011). Regulated deficit irrigation and 'Tommy Atkins' mango orchard productivity under microsprinkling in Brazilian semiarid. Engenharia Agrícola, Jaboticabal, 31(6): 1052-1053.

Cuenca, R.H. (1989). Irrigation system design: An engineering approach. Prentice Hall, Englewood Cliffs, 552.

Da Silva, A. C., A. P. de Souza, S. Leonel, M. E. de Souza, D. P. Ramos and A. A. Tanaka (2014). Growth and Flowering of Five Mango Cultivar under Subtropics Conditions of Brazil. Am. J. Plant Sci., 5: 393-402

De Azevedo, P. V. de, B. B. da Silva and V. P. R. da Silva (2003). Water requirements of irrigated mango orchards in northeast Brazil. Agricultural Water Management, 58 (3): 241-254.

Desmarais, G. (1996). Thermal characteristics of screen house configurations in a West-African tropical climate. Ph.D. Thesis. McGill University, Quebec, 172-177.

Doorenbos, J, and A.H., Kassam (1979). Yield response to water. FAO Irrigation and Drainage Paper No. 33, Rome, FAO. 33:1-57.

Dos Santos, M. R., M. A. Martinez, S. L. R. Donato and E. F. Coelho (2014). 'Tommy Atkins' mango yield and *photosynthesis under* water deficit in emiarid region of Bahia.

Dos Santos, M. R., S. L. R. Donato, E. F. Coelho, P. R. F. C. Junior and I. N. De Castro(2016). Irrigation deficit strategies on physiological and productive parameters of 'Tommy Atkins' mango. Rev. Caatinga, Mossoró, 29(1): 173 – 182.

Dos Santos, M.R., B.R. Neves, B.L. da Silva and S.L.R. Donato (2015). Yield, Water Use Efficiency and Physiological Characteristic of "Tommy Atkins" Mango under Partial Root zone Drying Irrigation System. J**.** Water Resource and Protection, **7**: 1029-1037.

FAOSTAT (2013). Food and Agriculture Organization of the United Nation (FAO). http://www.fao.org.

Ismail, S.M. (2002). Design and Management of Field Irrigation System. (In Arabic), 1st Ed Monsheat EL-Maaref. Puplication. Alexandria. Egypt

Jahurul M.H.A., I.S.M.Zaidul, K.Ghafoor, F.A. Al-Juhaimi, K. L. Nyam, N.A.N.Norulaini, F.Sahena and A.K.M. Omar (2015). Mango (*Mangifera indica* L.) by-products and their valuable components: A review. Food Chem., 183:173-180.

Jiskani, M. M., M. A. Pathan, K. H. Wagan and M. I. Khaskheli. (2007). Documentation of identified and to be identified disease of mango in Sindh, Pakistan. Abstracts. International Symposium on 'Prospects of Horticultural Industry in Pakistan (Future challenges & Production Prospects)' (28^{th} to 30^{th} March, 2007) organized by Institute of Horticultural Sciences, University of Agriculture Faisalabad- Pakistan, p. 13-14.

Karmeli, D. and J. Keller (1975). Trickle Irrigation Design. 1st Edition, Rain Bird Sprinkler Manufacturing Corporation, Glendora, 133 p.

Magness, J. R. and G. F. Taylor (1982). An improved type of pressure tester for the determination of fruit maturity. U. S. Depy. Agric. Circ., 50: 8 PP.

Mahadevan, A. and R. Sridhar (1986). Methods in physiological plant pathology. Sirakami publications 326.

Malik, C.P. and M.B. Singh (1980). Plant Enzymology and Histoenzymology. A text manual, Kalyani publishers, New Delhi**.**

Medany, M.A., M.A.A. Abdrabbo, A.A. Farag, M.K. Hassanien and A.F. Abou-Hadid (2009). Growth and Productivity of Mango Grown under Greenhouse Conditions. Egypt. J. Hort., 36 (2): 373-382.

Muchiri D.R., S.M.Mahungu and S.N. Gituanja (2012). Studies on Mango (*Mangifera indica* L.) kernel fat of some Kenyan varieties in Meru. J. Am. Oil Chemist's Society, 89: 1567-1575.

Pratima, P., N. Sharma and D. P. Sharma (2016). Canopy temperature and water relations of kiwifruit cultivar Allison in response to deficit irrigation and *in situ* moisture conservation. Current Sci., 111 (2): 250.

Ross, D.S. and S.A. Gill (1994). Insect screening for greenhouses. Agricultural Engineering Information Facts. FACTS 186.Univ. Maryland, College Park.

Schulzea, K., W.Spreera, A.Keilc, S.Ongprasertd and J. Müllera (2013). Mango (*Mangifera indica*, L. cv. Nam Dokmai) production in Northern Thailand—Costs and returns under extreme weather conditions and different irrigation treatments. Agric. Water Management, 126: 46- 55

Sharma, B.R., D. Molden and S. Cook (2015). Water use efficiency in agriculture: measurement, current situation and trends. In. Drechsel, P, Heffer, P., Magan, H., Mikkelsen, R., Wichlens, D. (Eds.) Managing Water and Fertiliser for Sustainable Intensification. Paris, France: Int. Fertiliser Association. pp. 39-64.

Snedecor, G.W. and W.G. Cochran (1990). Statistical Methods. Oxford and J.B.H. Bub.Com.6th Edition.pp:507.

Soothar, R. K., A. S. Chandio, M. S. Mirjat, M. A. Mangrio, M. U. Mirjat and M. A. Talpur (2016). Comparison of bubbler and basin irrigation methods in a bivarietal *Mangifera indica* orchard in Pakistan. Sci. Int. (Lahore), 27(2): 1229-1236

Spreer, W. and J. Müller (2011). Estimating the mass of mango fruit (*Mangifera indica*, cv. Chok Anan) from its geometric dimensions by optical measurement. Computers and Electronics in Agric., 75 125–131

Spreer, W., S.Ongprasert, M. Hegele, J. N. Wu¨ nsche and J. Muller (2009). Yield and fruit development in mango (*Mangifera indica* L. cv. Chok Anan) under different irrigation regimes Agric. Water Management, 96: 574 –584.

Tharanathan, R. N., H.M.Yashoda and T.N. Prabha (2006). Mango (*Mangifera indica* L.), the king of fruits – A review. Food Rev. Int., 22:95-123.

Vermeiren, L. and G.A. Jopling (1984). Localized Irrigation. FAO. Irrigation and Drainage paper no. 36, Rome, Italy.

Wei, J., G. Liu, D. Liu and Y. Chen (2017). Influence of irrigation during the growth stage on yield and quality in mango (*Mangifera indica L*). PLoS ONE 12(4): e0174498.

Yemm, E.W., and A. J. Willis (1954). The estimation of carbohydrate in extracts by anthrone. Biochem., J. 57: 508 – 514.

Yildirim, O., N. Halloran, Ş. Cavuşoğlu and N. Şengul (2009). Effects of different irrigation programs on the growth, yield, and fruit quality of drip-irrigated melon**.** Turk, J**.** Agric**.,** 33: 243-255.

Zuazo,V. H. D., C. R. R. Pleguezuelo and D. F. Tarifa (2011). Impact of sustained-deficit irrigation on tree growth, mineral nutrition, fruit yield and quality of mango in Spain. *Fruits,* 66(4): 257–268.

الملخص العربي

تأثير مستويات مختلفة من الري على نمو، محصول وجودة ثمار المانجو صنف كيت النامي تحت الشباك

محمود أحمد علي* جمال عبد الناصر خليل عبد المنعم أحمد اسماعيل*****

جمال فرج محمد بيومى***

* قسم الإنتاج النباتي – كلية الزراعة سابا باشا – جامعة الأسكندرية

** قسم الأراضى والكيمياءالزراعية – كلية الزراعة سابا باشا – جامعة الإسكندرية

*** المعمل المركزى للمناخ الزراعى – مركز البحوث الزراعية

أجريت هذه الدراسة خلال موسمين متتاليين ٢٠١٥ و ٢٠١٦ على أشجار مانجو (*Mangifera indica L*) صنف كيت عمرها ١٠ سنوات المزروعة في مزرعة البصيلي الحكومية في شمال غرب الدلتا بمحافظة البحيرة بمصر لدراسة تأثير طريقة الزراعة ومستويات الري المختلفة على نمو وجودة ثمار المانجو. تم توزيع المعاملات بتصميم القطع المنشقة مرة واحدة حيث طريقة الزراعة (الصوب الزراعية والحقل المكشوف ككنترول) في القطع الرئيسية، ورتبت مستويات الري (٥٠، ٧٥ و ١٠٠% من البخر– نتح المرجعى) في القطع تحت الرئيسية. اظهرت النتائج ان الزراعة فى الصوب الزراعية (الشباك) أعطت أعلى قيم لكل من النمو الخضري والمحصول وصفات جودة الثمار مقارنة بالزراعة فى الحقل المكشوف. كما ان النتائج أظهرت أن الرى عند مستوى ١٠٠٪ من البخر– نتح المرجعى أدى الى حدوث زيادة كبيرة في جميع الصفات المدروسة، بالمقارنة مع غيرها من المعاملات. النتيجة الهامة لهذه الدراسة هو توفير مياه الرى وزيادة إنتاجية اشجار المانجو.